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WATER SURFACE DYNAMIC'S OF THE STUDENA DAM, PERNIK USING SENTINEL 2A AND 2B SATELLITE DATA

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Abstract

This article presents the results of a study of the dynamics of the surface water area of the Studena dam using satellite images from Sentinel 2A and 2B. The period considered is from the beginning of 2019 to January 2020. The collected 35 cloud-free images from a total of 80 captured are organized in a spatial database in a GIS environment. A water index - MNDWI (Modified Normalized Difference Water) was used to determine the boundary of the water surface. The calculated areas for all images and their trends are analyzed by graph. For about seven months from the maximum annual area (0.91 km^2) in June, a rapid decrease of 0.10 km^2 per month is observed until the beginning of 2020, when the lowest value was measured – 0.23 km^2.

Introduction

The *Studena* Dam is located at the western end of *Vitosha* Mountain. It was built in the period 1953–1955 and was put into operation in 1955 for the purpose of water supply to the town of Pernik and the region. It is located on the Struma River next to the village of *Studena* and is part of the water balance of *Vitosha* Nature Park, [1–3]. It is therefore not allowed to fish and is protected. The area is 145.6 ha (1.456 km^2) [I.1]. During its operation, the amount of water (volume) and contour of the water mirror varied greatly. In the period 1982–1994, it decreased by half, with a decrease below the dead volume recorded in December 1993 to March 1994 [4]. In their study [5], the authors identified periods and conditions of longer drought of the dam, considering the period 2001–2017. Due to the endangering low quantities of water remaining and the growing social problem, the use of remote methods gives us reliable and accurate information about the dynamics of the water surface of the dam.

Study area

The study area is the *Studena* Dam, located at the western end of *Vitosha* Mountain, southwest of *Sofia*, near *Pernik* (Fig. 1). The specific purpose of the study is to track and analyze the dynamics of the water surface of the dam for 2019.

Materials and Methods

Images of European Sentinel-2A and Sentinel-2B satellites [I.2], launched under the Copernicus program, formerly known as GMES (Global Monitoring for Environment and Security), and were used to study the dynamics of the water surface of *Studena* dam. It is the European Earth observation and monitoring capacity building program [I.3].

The data from this pair of satellites is appropriate because of its high temporal resolution – every 5 days. The images are 10 m, 20 m and 60 m in spatial resolution. Each of the satellites is equipped with a multispectral sensor (MSI) with 13 spectral channels in the visible, near infrared (VNIR) and shortwave infrared (SWIR) (Table 1). The available spectral channels are suitable for accurate determination of the water-land boundary [6, 7]. Access to the image databases from the Copernicus Open Access Hub is free [I.2].

Table 1. Sentinel-2 spectral bands and spatial resolutions [I.4]

Band number (ρ)	**Central wavelength (nm)**	**Band width (nm)**	**Spatial resolution (m)**
1	443	20	60
2	490	65	10
3 (GREEN)	**560**	**35**	**10**
4	665	30	10
5	705	15	20
6	740	15	20
7	783	20	20
8	842	115	10
8a	865	20	20
9	945	20	60
10	1380	30	60
11 (SWIR)	**1610**	**90**	**20**
12	2190	180	20

A GIS database was created – a geographic information system for monitoring the *Studena* dam by satellite images.

The use of satellite images gives a true idea of the objects on the Earth's surface and their change over time and is a reliable source of information [6–8]. In this article, they are used to accurately estimate the change in the water surface area

of the *Studena* dam for the last one year. To determine the maximum water surface of the dam, a topographic map K-34-059-1 – Pernik [I.5] and an image from Google Earth, Image © 2020 Maxar Technologies, dated July 30, 2013, were used (Fig. 1) [I.6].

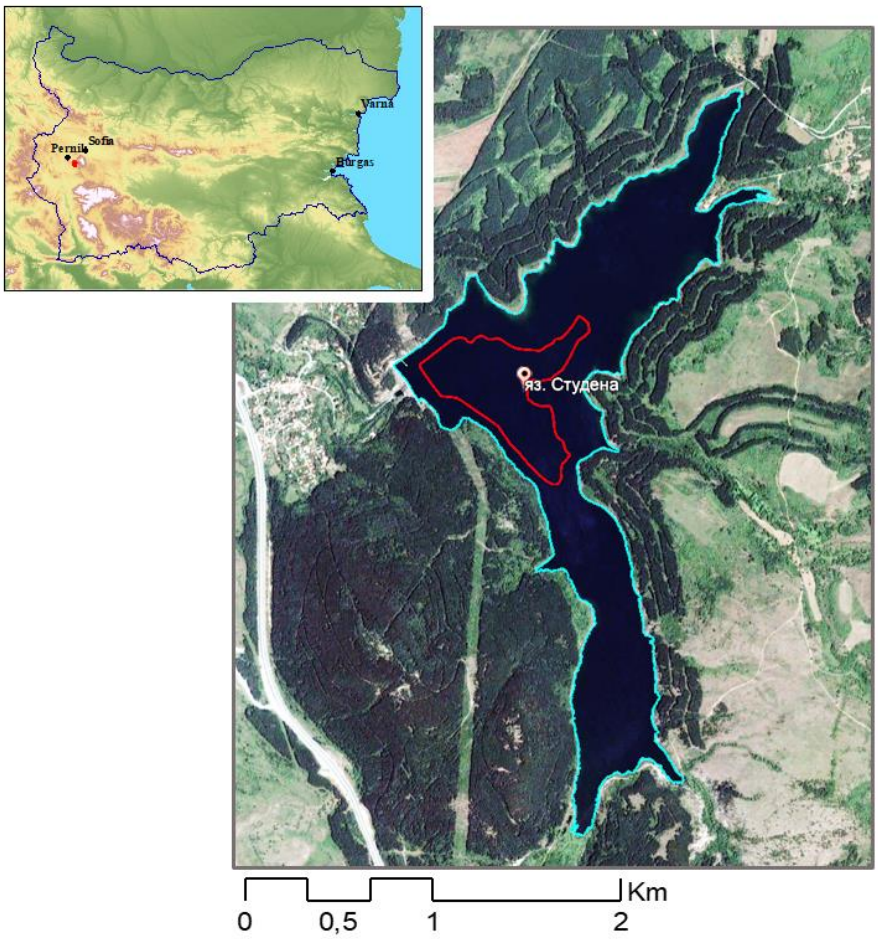

Fig. 1. Maximum (1.43 km^2, 30.07.2013) and minimum (0.23 km^2, 09.01.2020) water surface area of Studena dam [I.5]

Satellite data processing

For more accurate identification of the water surface, the generated water index – MNDWI (Modified Normalized Difference Water) was used, which combines the advantages of maximum absorption in the shortwave spectrum and

maximum reflection in the green spectral channel [9, 10]. The index is calculated by the formula:

1) $$MNDWI = \frac{\rho GREEN - \rho SWIR}{\rho GREEN + \rho SWIR'},$$

Where

$\rho GREEN$ is spectral channel 3 – green (560 nm),
$\rho SWIR$ is a spectral channel 11 – shortwave-infrared (1610 nm).

Geographic information systems (GIS) capabilities have been used to automatically calculate the index and extract the boundary of the water surface of the dam, and a model has been created for this purpose (Fig. 2).

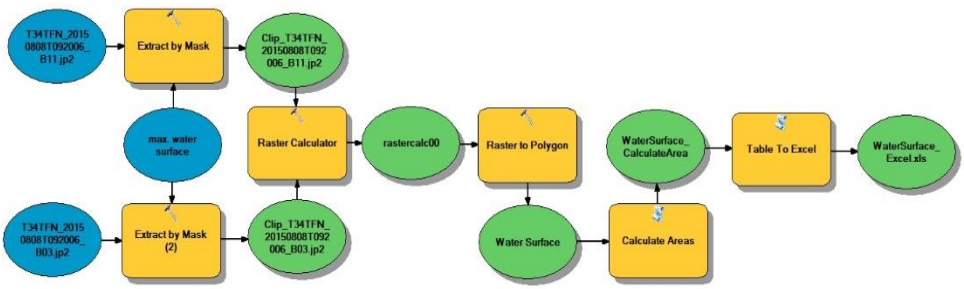

Fig. 2. Model water surface builder

Results and Discussions

The main problem with the satellite images used is the cloud cover masking effect. Only 35 cloudless images over the dam were studied from 80 taken from the Sentinel-2A and Sentinel-2B satellites during the study period (01/01/2019–29/01/2020). The normalized MNWI water index of formula 1) is calculated. On the basis of the obtained index images for each date, the contours of the water surface of the dam were extracted according to the model given in Fig. 2. The water surface areas have been calculated and the tendencies for stepwise decrease of their values and from there the quantities of water are clearly visible (Fig. 3).

The sharp decrease in the trends around the end of June and the beginning of July and the dates 01, 11 and 21 October is noticeable. The individual trends are characterized by a sharp decrease in the area of the water surface. The first decrease is at the end of July and is within 0.09 km^2. The second is with a greater difference of 0.24 km^2 and is observed in the first half of September. After 5–15 November until about 15 December, a steep decline was observed (a decrease of about 0.18 km^2), reaching a value of 0.23 km^2 at the end of the year. At the beginning of

2020 (09.01.2020) the minimum value of the water surface of the *Studena* Dam – 0.23 km^2 – was reported.

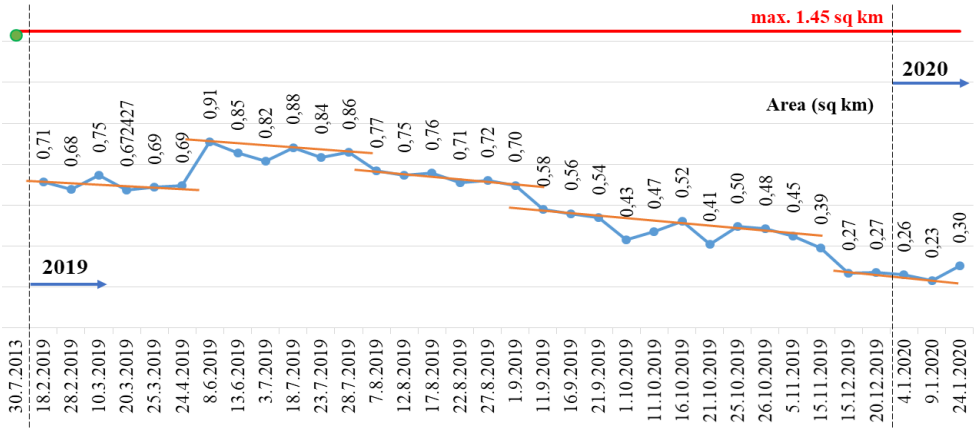

Fig. 3. Dynamics of the water surface area of the Studena dam in the studied period

In Fig. 1. the significant difference between the maximum measured in July 2013 and the minimum value in January 2020 of the water surface area of the dam is clearly visible.

The increase of the water surface at the end of January 2020, after the measures taken earlier, makes a positive impression.

The increase of the water surface area in May 2019 is clearly visible due to more rainfall (all images from May have a dense cloud cover).

Conclusion

In conclusion, the analysis of the satellite imagery data confirms the clear tendency to decrease the water surface area in 2019. There are clear sharp reductions in area and, accordingly, the amount of water around the dates 03 and 23 July, 01, 11 and 21 October, 15 December.

The upward trend at the end of January 2020 gives optimistic hope.

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ДИНАМИКА НА ВОДНАТА ПОВЪРХНОСТ НА ЯЗОВИР СТУДЕНА, ГР. ПЕРНИК С ИЗПОЛЗВАНЕ НА ИЗОБРАЖЕНИЯ ОТ SENTINEL 2A и 2B

Г. Желев

Резюме

В тази статия са представени резултати от изследване на динамиката на площта на водната повърхност на язовир „Студена“ с използване на спътникови изображения от Sentinel-2A, -2B. Разгледаният период е от началото на 2019 г. до януари 2020 г. Събраните 24 броя изображения са организирани в пространствена база данни в среда на ГИС. Използван е воден индекс – MNDWI (Modified Normalized Difference Water), с помощта на който е определена границата на водната повърхност. Изчислените площи за всички изображения и техните тенденции са анализирани чрез графика. За около седем месеца от максималната за годината площ през месец юни се вижда бързото намаляване със средно 0.10 km^2 месечно до началото на 2020 г., когато на 09 януари е измерена най-ниската стойност – 0.23 km^2.